APTD-0717
314

PB 202 168

RESTRICTIONS ON THE USES OF COAL

JUNE 1971

Conducted in cooperation with the
Office of Air Programs of the Environmental
Protection Agency by the Bureau of Mines
under a working fund agreement

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES
MINERAL SUPPLY

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Introduction

Although the United States has virtually unlimited reserves of coal of all ranks, the future availability of domestic coals may be limited by a number of factors that range from the inherent characteristics of the coal itself to the Nation's capacity for producing and transporting a high grade product suitable for various end-use markets.

Coals vary greatly in chemical and physical properties and, in most instances, one rank of coal can not be substituted directly for another without major changes in burning equipment and methods of preparation and processing. Even coals of the same rank can not, many times, be used to replace other coals. This applies particularly to the coking coals, which must be used for coke production, and to the coals with low ash-fusion temperatures, which are required for use in wet-bottom furnaces. Ash, sulfur, and volatile matter content also are critical parameters of coal when it is burned in certain types of combustion equipment.

Bureau of Mines projections indicate that coal requirements of the United States will increase greatly within the next decade. Therefore, in addition to coal's quality characteristics that may restrict its use in certain markets, other limiting factors such as manpower and transportation availability, and inadequate mine production and preparation and cleaning plant capacity are directly related to coal supply and availability. Though data were lacking in some areas, these constraints, as well as those concerned with the quality characteristics of coal, were evaluated in this report and an attempt was made to show their quantitative effect upon the future consumption and use of coal.

Air pollution control regulations have restricted the burning of high sulfur (more than 1 percent) coals in many parts of the United States and a problem of immediate concern to electric utility plants in some areas is the procurement of low sulfur coals with ash-fusion temperatures suitable for use in wet-bottom furnaces. One part of this study, which was developed from data supplied by electric-utility plants to the Federal Power Commission, has assessed the current requirements for low ash-fusion temperature coals of electric utilities in various geographical areas. The tabular data in this report show that about five-sixths of the 68 million tons of coal reportedly consumed in wet-bottom furnaces in 1969 contained more than 2 percent sulfur. With the passage of more stringent air pollution control regulations, the problem of coal supply for these plants will become increasingly severe because the total production of low-sulfur coals with low ash-fusion temperatures in 1969 was less than 35 million tons.

Manpower needs of the coal industry were projected for 1975, 1980, and 1985 using Bureau of Mines projections of bituminous coal demand in these years and assuming various levels of productivity. Even with the lower assumed rate of growth for productivity, which was less than that recorded between 1968 and 1969, manpower requirements could increase by 90,000 men in 1980 and 143,000 men in 1985.

An adequate transportation system for transporting coal from mines to markets is one of the most important factors in coal availability. The number of railroad hopper cars available for transporting coal has declined by about 35,000 during the past 5 years and it is indicated that the number will decline further unless incentives such as governmental

assistance in financing new cars are made available to railroads with insufficient earnings to conduct their own car-building program. However, other actions, such as the doubling of demurrage rates by the Interstate Commerce Commission to discourage the accumulation of railroad cars at transshipping facilities and consumer plants, and the expansion of coal transportation on inland waterways may ease the coal transportation burden presently consigned to railroads.

The development of adequate productive, preparation, and cleaning capacity is, of course, a requisite for adequate supply. No data are available, but it is thought that annual productive capacity to supply domestic demand will have to increase from the present level of about 600 million to nearly 1 billion tons by 1985. Coal preparation and cleaning capacity will have to expand at an even greater rate because of the more severe requirements being imposed upon coal quality.

PB-202 168

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-0717	2.	3. Recipient's Accession No.
4. Title and Subtitle Restrictions on the Uses of Coal			5. Report Date June 1971 6.
7. Author(s)			8. Performing Organization Rept. No.
9. Performing Organization Name and Address United States Department of the Interior Bureau of Mines - Mineral Supply 4800 Forbes Avenue Pittsburgh, Pennsylvania 15213			10. Project/Task/Work Unit No. 11. Contract/Grant No.
12. Sponsoring Organization Name and Address Environmental Protection Agency Office of Air Programs Research Triangle Park, North Carolina 27711			13. Type of Report & Period Covered 14.

15. Supplementary Notes

16. Abstracts

Although the United States has virtually unlimited reserves of coal of all ranks, the future availability of domestic coals may be limited by factors which range from the inherent characteristics of the coal itself to the nation's capacity for producing and transporting a high grade product suitable for various end-use markets. In addition to coal's quality characteristcs that may restrict its use in certain markets, other limiting factors such as manpower and transportation availability, and inadequate mine production and preparation and cleaning plant capacity are indirectly related to coal supply and availability. Each of these constraints were evaluated in this report and an attempt was made to show their quantitative effect upon the future consumption and use of coal.

17. Key Words and Document Analysis. 17a. Descriptors

Coal
Availability
Limiting
Coal constituents
Transporation
Coal preparation
Coal mining
Manpower
Safety

17b. Identifiers/Open-Ended Terms

17c. COSATI Field/Group 21D

18. Availability Statement Unlimited	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 62
	20. Security Class (This Page UNCLASSIFIED	22. Price

Chemical and Physical Properties of Coal

Coals commonly moved to respective consumer markets may vary widely in chemical and physical properties, depending, first, upon the coal's general utilization and, secondly, upon its specific application to a given process. The degree of acceptability of certain coals to its end-use is commonly referred to as the quality of those specific type coal supplies. For example, coals moving to coke plants to produce coke for foundries and steel plants are evaluated physically by the degree to which they form strong coke residues and the degree to which they expand during the coking process. On the other hand, these coals must also meet requirements which limit the amount of undesirable chemical and inert materials inherent in the coal. Some of the more limiting factors of coking coals, assuming they display satisfactorily strong physical properties, are their ash and sulfur contents. Ash is undesirable because it is of no practical value to the steel making process, and sulfur because it imparts an undesirable quality to the pig iron and must be removed by further processing, and at an added cost. For these reasons, primarily, coking coals having low sulfur contents (generally 1 percent or less) and low to medium ash content (6 to 8 percent) preferentially are moved to the coke production industry.

Coals destined to find utilization as fuel for combustion processes likewise are categorized as to their acceptability or compatibility to one or more specific types of coal combustion equipment. Fundamentally, combustion units are classed by type as fuel-bed burning, suspension burning, or cyclone burning. Each appears to fall into general patterns which depend to a great degree on size and characteristics of the coal to be utilized. Some combustion unit designs are more tolerant of coal

quality differences than are others. Indeed, some combustion units are designed specifically to handle a wide variety of coals of differing characteristics, while other units are designed to take advantage of selected coal characteristics such as coal size, grindability, free swelling index, moisture, volatile matter, and ash-fusion temperature. Examples of such combustion unit designs are the spreader stoker-fired units, which can handle a wide variety of coals; the hopper-fed chain grate, which recognizes the limiting factors of moisture and a low to medium (4 to 6) free swelling index of the coal; and the slag-tap furnaces, which require coal with an ash-fusion temperature in the low to mid-fusion temperatures (2000-2600^{o}F), with attendant ash viscosity tolerances on the upper part of that ash-fusion temperature range; and the pulverized coal (PC) furnaces which favor the more easily ground coals.

The evolution of industrial and utility combustion equipment in the last 20 to 30 years is remarkable. Where once plant capacity was realized from several medium sized units, it now consists of comparatively much larger and more highly efficient units. To a great degree, increased knowledge of the inherent coal characteristics allowed boiler designers to capitalize on those characteristics and to design units specifically to take advantage of heretofore undesirable coals. The slag tap furnace is one case where the low ash fusion (which is generally a negative factor in the selection of a boiler fuel) was made to work to the advantage of the combustion process. These furnaces are quite different from

the dry-ash furnaces which use finely pulverized coal and require coal with a high ash-fusion temperature as most of the ash escapes through the hot screen tubes in the rear of the boiler. A coal with low ash-fusion utilized in a pulverized coal furnace would result in ash deposition on these tubes with eventual boiler failure resulting. On the other hand, with the slag-tap design, a low ash fusion is desirable for the system because it is specifically designed to remove the ash in molton form from the combustion chamber walls.

As a part of this coal restrictions study, the Federal Power Commission was consulted and permission was granted the Bureau of Mines to extract selected data from FPC's current canvass of the electric utilities. Data related to the quality of steam coals consumed in electric-utility plants are presented with respect to the type of combustion equipment utilized. The data are arranged in several forms to show the significance of coal quality.

The data presented represent about 80 percent coverage of all U.S. electric-utility plants which were canvassed by FPC and are believed to be representative of the wet-bottom furnace population in the U.S.

Table 1A indicates, by FPC area, the number of wet-bottom or slag-tap furnaces reported and the quality and quantity of the coals consumed.

Table 1B displays these data on a State basis.

These data are arranged in Tables 2A and 2B to show the distribution of sulfur ranges with respect to the coals consumed in wet-bottom furnaces. It is noted that over 56 million tons of the 68 million tons of coal reportedly consumed in wet-bottom furnaces possess sulfur contents of 2 percent or greater. Those coals of course are not considered permissable

TABLE 1A. - Coal Consumption at Electric-Utility Plants in FPC Areas with Wet- and Dry-Bottom Furnaces, in 1969

FPC Area	Number of Plants with Wet-Bottom Furnaces	Coal Consumption (Thousand Short Tons)		Coal Analyses			Plant Fuel Requirement
		In Wet Furnaces	In Dry Furnaces	Percent Ash	Percent Sulfur	Btu/lb.	Percent Coal
Chicago	45	23,003	11,071	11.7	3.27	11,056	93
Ft. Worth	8	326	417	11.9	3.02	11,795	52
New York	31	24,111	3,971	12.4	2.88	12,158	95
Atlanta	19	20,224	1,170	12.5	2.47	11,379	89
San Francisco	1	631	---	6.6	0.50	12,673	65
Total	104	68,295	16,629	12.1 (average)	2.87 (average)	11,556 (average)	92 (average)

TABLE 1B. - Coal Consumption at Electric-Utility Plants in the United States with Wet- and Dry-Bottom Furnaces, in 1969

State	Number of Plants with Wet-Bottom Furnaces	Coal Consumption (Thousand Short Tons)		Coal Analyses			Plant Fuel Requirement
		In Wet Furnaces	In Dry Furnaces	Percent Ash	Percent Sulfur	Btu/lb.	Percent Coal
Alabama	2	2,000	650	13.9	2.09	12,094	100
Colorado	2	40	406	12.6	0.40	9,932	10
Dist. of Columbia	1	451	---	10.2	1.40	13,228	67
Florida	1	2,286	---	11.9	3.80	11,280	90
Georgia	5	6,729	---	9.9	1.41	11,153	86
Illinois	13	9,784	7,280	13.3	3.73	10,304	93
Indiana	7	8,434	1,250	11.3	3.42	11,091	98
Iowa	10	1,488	452	10.1	3.01	11,039	78
Kansas	3	168	---	12.7	3.20	11,340	42
Kentucky	2	5,054	---	16.8	4.02	10,592	100
Maryland	1	896	---	8.0	2.40	13,582	97
Massachusetts	2	1,065	---	8.4	1.13	13,084	97
Michigan	7	3,020	921	9.8	1.77	12,597	97
Minnesota	2	1,740	217	11.0	3.22	11,501	91
Missouri	3	118	11	10.6	3.63	11,416	80
Nevada	1	631	---	6.6	0.50	12,673	65
New Hampshire	1	953	---	6.9	2.50	13,500	100
New Jersey	6	3,459	218	10.0	2.40	13,155	73
New York	7	3,390	952	13.5	2.45	12,411	100
North Carolina	1	536	---	13.4	1.80	12,352	96
Ohio	8	5,587	2,337	13.5	4.09	11,666	100
Pennsylvania	3	3,560	621	16.6	2.22	12,068	100
South Carolina	4	1,975	---	11.9	1.13	12,496	74
Tennessee	1	1,382	---	9.4	2.80	12,070	64
Virginia	3	262	520	7.7	1.13	13,692	100
West Virginia	2	722	591	17.2	4.01	11,167	100
Wisconsin	6	2,565	203	10.3	2.79	11,655	95
Total	104	68,295	16,629	12.1 (average)	2.87 (average)	11,556 (average)	92 (average)

TABLE 2A. - Coal Consumption in Wet-Bottom Furnaces at Electric-Utility Plants in FPC Areas, by Sulfur Content, in 1969

FPC Area	Number of Plants with Wet-Bottom Furnaces	Coal Consumption (Thousand Short Tons)		
		Less than 2.0 Percent	2.0-3.0 Percent	More than 3.0 Percent
Chicago	45	1,979	4,801	16,223
Ft. Worth	8	40	---	286
New York	31	1,760	12,175	10,176
Atlanta	19	7,373	5,511	7,340
San Francisco	1	631	---	---
Total	104	11,783	22,487	34,025

TABLE 2B. - Coal Consumption in Wet-Bottom Furnaces at Electric-Utility Plants in the United States, by Sulfur Content, in 1969

State	Number of Plants with Wet-Bottom Furnaces	Coal Consumption (Thousand Short Tons)		
		Less than 2.0 Percent	2.0-3.0 Percent	More than 3.0 Percent
Alabama	2	---	2,000	---
Colorado	2	40	---	---
District of Columbia	1	451	---	---
Florida	1	---	---	2,286
Georgia	5	4,600	2,129	---
Illinois	13	---	1,499	8,285
Indiana	7	---	---	8,434
Iowa	10	2	543	943
Kansas	3	---	---	168
Kentucky	2	---	---	5,054
Maryland	1	---	896	---
Massachusetts	2	1,065	---	---
Michigan	7	1,977	1,043	---
Minnesota	2	---	---	1,740
Missouri	3	---	---	118
Nevada	1	631	---	---
New Hampshire	1	---	953	---
New Jersey	6	---	3,393	66
New York	7	242	3,148	---
North Carolina	1	536	---	---
Ohio	8	---	227	5,360
Pennsylvania	3	2	3,558	---
South Carolina	4	1,975	---	---
Tennessee	1	---	1,382	---
Virginia	3	262	---	---
West Virginia	2	---	---	722
Wisconsin	6	---	1,716	849
Total	104	11,783	22,487	34,025

under most of the current fuel regulations now in effect or being considered in many of the geographical areas where wet-bottom furnaces are currently operated.

While FPC did not collect information with respect to fuel other than that shown in the above referenced tables, Bureau knowledge of other characteristics (IC 7923, Fusibility of Ash of U.S. Coals) of these coals reveals that essentially all this reported coal (86 million tons) are below the critical ash-fusion temperature (2600°F). Replacement of coal supplies, currently being moved preferentially to wet-bottom furnaces, with coals of low sulfur content is not a simple coal substitution. While some of the lower sulfur coals could be expected to possess ash fusion temperatures compatible to wet-bottom furnaces, the bulk of those quality coals would have ash-fusion temperature well above the 2600°F limit and be totally unsuited to continuous boiler operation. In general, boiler modifications to allow use of higher fusion coal would not be economically feasible.

The cyclone furnace is not the only type of coal combustion equipment whose successful operation depends upon the judicious selection of coal for ash characteristics. The pulverized coal-fired furnace requires coal with select ash fusion above 2400-2500°F. Probably the most common broad classifications of coals with respect to combustion are the tendencies for the coal particles to either fuse together or to remain separate during the combustion process. These characteristics are commonly referred to as caking and free-burning characteristics, respectively. Pulverized coal-fired (PC) units require coals that are free-burning as opposed to the cyclone which can use the caking variety. In addition the PC units,

by virtue of the degree to which the coal size must be reduced, require coals that are easily ground (low coal grindability). Aside from the critical factors of ash-fusion temperature and grindability, the PC units can effectively handle all ranks of coal and are the most versatile of all boilers.

In the industrial and smaller boiler applications, several types of combustion systems have been developed--each with its particular operation characteristics with respect to coal requirements. Some indication of the different firing methods developed, the types of coal utilized and the size ranges for each method are shown in Table 3. Table 4 further indicates the degree to which these methods display sensitivity of operation with respect to coal characteristics. A study by Professor T. S. Spicer, Pennsylvania State University, of the methods shown in these tables revealed the following conclusion:

(1) The "single-retort stoker" will burn all coals from anthracite to lignite but not necessarily with equal success. Characteristics such as size consist, ash fusibility, and degree of caking nature are important and tend to influence the performance.

(2) The "multiple-retort stoker" performs best with the eastern caking bituminous coals. As in the single-retort stoker, size consist, ash fusibility and degree of caking are important properties.

TABLE 3. - Industrial Combustion Equipment Applications

Method of Firing	Types of Coal			
	Anthracite	Bituminous-Caking (Eastern Area)	Bituminous, Free-Burning (Midwestern)	Sub-bituminous & Lignites (Western)
	Range of Boiler Capacity in Pounds of Steam Per Hour			
Single-Retort Underfeed	1,000-10,000	1,000-35,000	5,000-30,000	---------
Multiple-Retort Underfeed	---------	30,000-500,000	---------	---------
Spreader Stokers	---------	5,000-200,000	5,000-200,000	5,000-200,000
Traveling Grate	10,000-200,000	10,000-200,000 1/	---------	10,000-200,000
Chain Grate	---------	---------	10,000-200,000	---------
Pulverized Coal 2/	60,000-1,000,000	60,000-1,000,000 and over	60,000-1,000,000 and over	60,000-1,000,000 and over
Cyclone Furnace 3/	---------	75,000-350,000 per furnace	75,000-350,000 per furnace	75,000-350,000 per furnace

NOTE: 1/ Limited case.
2/ Certain coals with proper ash fusion.
3/ Steaming range may exceed maximum figures shown.

SOURCE: COAL UTILIZATION, May, 1956. "Coal--Bedrock of Industrial Progress" by T. S. Spicer

TABLE 4. - Coal Properties Significance Chart For Combustion Performance

	Stokers *					
	S.R.	M.R.	T.G.	S.S.	P.F.	Cyclone
1. Size consist (as fired)--	V	I	I	V	V[1/]	V
2. Moisture [2/] ----------	M	M	N	M	V	M
3. Caking Index [3/] ---------	I	I	V	M	N	N
4. Ash Fusibility ----------	I	I	M	M	I	V
5. Grindability ----------	N	N	N	N	V	N
6. Friability ----------	M	M	M	M	N	N
7. Volatile Matter ---------	M	M	M	M	I	M
8. Fixed Carbon ----------	N	N	N	N	M	N
9. Ash Content ----------	M	M	M	M	M	M
10. Calorific Value ---------	N	N	N	N	N	N
11. Ash Viscosity ----------	M	M	M	M	I	V
12. Ash Composition --------	--See Footnote 4--					
13. Sulfur ----------	--See Footnote 5--					

Rating Code: V Very important.
I Important.
M Minor importance.
N Little or no importance.

* Abbreviations shown below are for the respective methods listed in Table 3.

1/ Degree of fineness is a better term for P.F.
2/ Surface moisture is more critical than inherent moisture. Moisture is very important from the standpoint of plant flowability.
3/ Some engineers are attempting to use the F.S.I. as an index of the degree of caking.
4/ Ash composition is very important as it affects fireside fouling, but not important to combustion.
5/ Sulfur is important from a corrosive standpoint, but not important to combustion.

(3) "Spreader stokers" will handle all ranks of coal except anthracite. Size consist appears to be the most important single characteristic for this stoker. Other characteristics are of secondary importance in coal selection.

(4) "Traveling-grate stokers" can handle every type of solid fuel with the exception of strongly caking bituminous coals. Recent experiments with careful sizing to eliminate fines indicate that even these coals may be used with proper precautions. The combination of the degree of free burning versus size consist has been carefully studied in selecting coal for this stoker.

(5) "Pulverized firing" appears to be the most universal method of firing coal because all ranks of fuels may be used. Admittedly, the customer prefers coals which are easiest to burn, most economical to use, and which require the minimum capital outlay. Ease of grindability and ash fusion characteristics are probably the two most important characteristics to watch. The choice of wet- or dry-bottom furnace and the selection of suitable unit furnace heat release, extend the latitude of the ash fusibility range while still securing optimum performance.

(6) Thus far, "Cyclone firing" has not attained the versatility of pulverized firing in handling as wide a range of coals. Ash characteristics and size consist

appear to be the most important fuel characteristic.

In spite of the limitations cited above, the manufacturer states that 70 percent of the bituminous and lignite coals produced in the United States are considered suitable for use in cyclone furnaces.

Despite the difficulty encountered in trying to correlate the many characteristics of coal with actual performance, an attempt has been made to summarize the significant relationship in Table 4. The author is well aware of the hazards involved in such an effort, but feels that at least it will stimulate future consideration of this matter. The values in the chart are intended to indicate the relative importance in the overall picture of a given combustion technique. The quality of the properties considered is for the average range instead of the extremes. Moreover, the chart should be used more as a "rule of thumb" for design considerations than as a guide for an existing plant, where obviously certain characteristics are of paramount importance due to limiting design deficiencies. Actually, the combination of two or more properties changes the significance of a single item. For instance, size consist and caking qualities, or size consist and moisture content often present an entirely different degree of relative importance than when considered separately.

Manpower Limitations

One aspect of coal mining that may have a serious limiting effect upon future coal availability is an adequate supply of manpower. Since 1949, production of bituminous coal and lignite in the United States has increased about 25 percent. During the same period, employment in these industries has decreased 70 percent. Approximately 300,000 less men were employed in this industry in 1968 than were employed in 1949.

The large decrease in manpower is attributed principally to the mechanization of mining operations. However, other factors such as the closing of many marginal mining operations and the large increase in production by strip-mining methods have contributed also to the decline.

A total of 124,532 men was employed in the production of bituminous coal and lignite in the United States in 1969. The industry operated an average of 226 days during the year and production averaged 19.90 tons per man day, or 4,497 tons per man year.

About 80 percent of the total number of employees (99,269 men) was employed in underground mining in 1969; 18 percent (22,323 men) was employed in strip mining; and the remainder (2,940 men) was employed in auger mining. Employment by type of mining has changed considerably in recent years, however. Whereas between 1965 and 1969, employment in underground mining decreased by more than 10,000 men, 594 more men were working in strip mines and 672 more men were working in auger mines in 1969 than in 1965.

Productivity in the bituminous-coal industry, measured in tons of output per man per day, has increased from 12.83 tons in 1960 to 19.90 tons in 1969. This increase represented an average annual rate of growth of 5.0 percent for the last 9-year period. During the past 5 years, productivity increased at an average annual rate of growth of 4.25 percent. Between 1967 and 1969, however, the growth rate declined to about 1.5 percent.

A number of interrelated factors influence productivity in bituminous coal and lignite mining, but the principal factors contributing to the lower productivity gains of recent years were the smaller growth rates for coal production by strip mining, and the decline in the rate of mechanization of underground mines.

Overall increases or decreases in productivity in the future will depend principally upon the type of mining as productivity varies tremendously according to method of production. In 1969, productivity in terms of tons of output per man day varied from 39.88 tons for auger mines, to 35.71 tons for strip mines, to 15.61 tons for underground mines.

Because of the implementation of recently enacted health and safety regulations, and because much of the potential of mechanization appears to have been reached, future gains in productivity will probably not exceed 2 percent annually and may even be closer to 1 percent. In fact, there is some speculation that productivity may remain at about the 1969 rate, or actually decline slightly, until about 1985.

Approximately 80 percent of the bituminous coal is produced in unionized mines and the bulk of the unionization is associated with underground mining. In the event of a general industry strike, it may be assumed that virtually all underground mines would cease to operate. With such a curtailment of production, domestic coal supply would decline by about two-thirds and, in terms of current domestic requirements, there would be a shortage of about 300 million tons of coal for domestic markets.

Table 5 shows production and employment data in the bituminous coal and lignite mining industries from 1960 through 1969, and Tables 6, 7, and 8 shows similar data projected for 1975, 1980, and 1985 at various levels of productivity. Lignite mining is included because there are no separate data for the lignite mining industry. The data are not affected by this inclusion, however, because lignite production represents only a fraction of 1 percent of the total output of both fuels. Future lignite production will have, however, increasing significance.

The analysis of manpower requirements for assumed increases in productivity was based upon long-range Bureau of Mines projections for bituminous coal demand and production for the year 2000 that will be published in a forthcoming 1970 issue of the Bureau's Mineral Facts and Problems series. The low projection, based upon the assumption of present end uses of coal, corresponds to a production figure of 850 million short tons in 1985. The high projection, based principally upon the assumption that economically competitive synthetic liquid and gaseous fuels become available, corresponds to a 1985 production figure of 1,350 million short tons. Data for 1975 and 1980 were based upon the same assumptions.

TABLE 5. - Production and employment data in the bituminous coal and lignite mining industries, 1960-1969

Year	Production, million short tons	Men employed	Days worked, average per year	Productivity, tons/man/day
1960----	415.5	169,400	191	12.83
1961----	403.0	150,474	193	13.87
1962----	422.1	143,822	199	14.72
1963----	458.9	141,646	205	15.83
1964----	487.0	128,698	225	16.84
1965----	512.1	133,732	219	17.52
1966----	533.9	131,752	219	18.52
1967----	552.6	131,523	219	19.17
1968----	545.2	127,894	219	19.37
1969----	560.5	124,532	226	19.90

TABLE 6. - Projected production and manpower requirements in the bituminous coal and lignite mining industries at the 1969 rate of productivity 1/

Year	Required production, million short tons		Manpower Requirements			
			High		Low	
	High	Low	Number	Increase over 1969	Number	Increase over 1969
1975-----	796	670	181,818	57,286	153,038	28,506
1980-----	1,035	780	236,403	111,871	178,164	53,632
1985-----	1,350	850	308,360	183,828	194,153	69,621

1/ Based upon an average work year of 220 days.

TABLE 7. - Projected production and manpower requirements in the bituminous coal and lignite mining industries at 1% average annual rate of growth in productivity 1/

Year	Required production, million short tons		Manpower Requirements			
			High		Low	
	High	Low	Number	Increase over 1969	Number	Increase over 1969
1975-----	796	670	174,370	49,838	146,769	22,237
1980-----	1,035	780	214,819	90,287	161,893	37,361
1985-----	1,350	850	267,496	142,964	168,424	43,892

1/ Based upon an average work year of 220 days.

TABLE 8. - Projected production and manpower requirements in the bituminous coal and lignite mining industries at 2% average annual rate of growth in productivity 1/

Year	Required production, million short tons		Manpower Requirements			
			High		Low	
	High	Low	Number	Increase over 1969	Number	Increase over 1969
1975-----	796	670	162,615	38,083	136,874	12,342
1980-----	1,035	780	192,022	67,490	144,712	20,180
1985-----	1,350	850	226,267	101,735	150,845	26,313

1/ Based upon an average work year of 220 days.

Tables 6, 7, and 8 show projected high and low manpower requirements in 1975, 1980, and 1985 at various levels of productivity necessary to meet projected coal requirements in these years, assuming a constant work year of 220 days. It is impractical to attempt to predict precisely productivity gains of the future, but a reasonable assessment appears to be an average annual rate of growth of 1 percent. At this growth rate and an assumed average of 220 days worked per year, manpower requirements for producing the projected low range of outputs will be 18 percent higher in 1975, 30 percent higher in 1980, and 35 percent greater in 1985. At the projected high range of output, corresponding manpower increases will be 40 percent in 1975, 73 percent in 1980, and 115 percent in 1985. These percentage increases represent additional manpower requirements varying between 22,237 and 49,838 men in 1975, 37,361 and 90,287 men in 1980, and 43,892 and 142,964 men in 1985. These data are shown in Table 7.

Table 6 shows similar data based upon the 1969 rate of productivity, and Table 8 shows projected manpower requirements if productivity increases at an average annual rate of 2 percent. At the 1969 rate of an average output of 19.90 tons per man per day, additional manpower requirements to meet the projected high output will range from 57,286 men in 1975 to 183,828 men in 1985. Projected low demand at the 1969 productivity level can be met if there are approximately 29,000 additional workers in 1975, 54,000 additional workers in 1980, and 70,000 additional workers in 1985.

With a 2.0 percent average annual increase in productivity, additional manpower requirements at the high and low levels of demand will range from 12,342 to 38,083 men in 1975; 20,180 to 67,490 men in 1980; and 26,313 to 101,735 men in 1985.

Table 9 shows the potential output of bituminous coal and lignite in 1975, 1980, and 1985, at various levels of productivity if manpower for production remains at the 1969 level and working days per year remain constant. The data shown in this table indicate that production in these years will, in all instances, fall below the Bureau of Mines projected low level of demand in these years, even with an assumed average annual rate of growth in productivity of 2 percent.

Four States - Illinois, Kentucky, Pennsylvania and West Virginia account for approximately three-fourths of the bituminous coal production. These States also employ about three-fourths of the total number of men producing bituminous coal. Unfortunately, these States have the lowest supply of available labor. According to Bureau of the Census data, the National growth rate for available male labor in the United States in the 18-64 year category is nearly twice that of the four-mentioned coal producing States. West Virginia, in particular, has the greatest potential shortage of manpower, followed in order by Pennsylvania, Kentucky, and Illinois.

It is beyond the scope of this report to attempt to assess potentially available manpower for coal mining in the future, but it should be recognized that, in addition to the increased numbers of new miners that will be needed, there will be an additional man-power requirement to replace

TABLE 9. - Projected production of bituminous coal and lignite in the United States at various rates of productivity

	Production				Days worked, average per year	Manpower availability 3/
			Projected Required			
	Million short tons 1/	Million short tons 2/	High, million short tons	Low, million short tons		Number of miners
1975-----	595.0	631.2	796.0	670.0	220	124,532
1980-----	625.3	696.9	1,035.0	780.0	220	124,532
1985-----	657.2	769.5	1,350.0	850.0	220	124,532

1/ Based upon a 1% average annual rate of growth in productivity.

2/ Based upon a 2% average annual rate of growth in productivity.

3/ Average number of men working daily in 1969.

workers lost by death, retirement, or transfer to other work. Retirement, however, will claim the greatest number as a recent Bureau of Mines study for internal use has concluded that the age distribution of miners currently employed shows a peak at 51 years.

Recruiting young men for work in the coal mines may become increasingly more difficult because of the poor public image of the industry, the hazardous nature of the work and adverse publicity stemming from mine disasters, and the remote location of mines from readily accessible urban areas. It may be expected that there will be also a limited number of mining engineers and supervisory mining personnel available during the next decade because fewer college students are pursuing mining as a course of study.

On the positive side, the coal mining manpower problem has attracted the attention of the Congress where a bill recently was introduced to relax immigration regulations to permit experienced foreign miners to migrate to the United States if they agree to work in coal mines. This, however, would be only a temporary solution to the problem. The real solution should be directed toward long-term remedies. These could be programs that include training in vocational schools established by the government or industry or scholarship grants for young men who would agree to study mining engineering as a career.

Transportation Limitations

An adequate supply of transportation equipment, particularly railroad hopper cars, for moving coal from mines to markets, is one of the most important facets of coal availability. Except for unit train loadings there is little or no storage of bituminous coal at the mines and coal mines cannot operate without regular supply and a sufficient number of railroad cars. At the same time, transportation costs represent a substantial portion (more than 60 percent above the f.o.b. mine value) of the delivered price of coal, and so are significant in coal's competition with other energy sources, particularly oil and natural gas, which are transmitted by pipelines at lower cost.

One of the principal factors contributing to coal shortages during 1970 was a 35,000 decrease in the number of railroad hopper cars available for coal transportation in the past 5 years. Although most of the decrease was attributed to retired cars of the old 50-60 tons capacity class, their capacity was equivalent to around 50 million tons of annual coal production, on the basis of 28 turnarounds per year. This production could have been taken care of by one-half as many of the newer 100-ton cars. On a car-for-car basis, with the larger cars the production equivalent would have been in excess of 95 million tons.

These figures do not include cars owned by large consumers, particularly electric power utilities, or by coal producing companies. Most of these cars are used in unit trains which, together with unit train cars owned by the railroads, have substantially improved car efficiencies, including the need for fewer cars, with corresponding

cost savings. It is estimated that unit trains and other train-loads carry approximately one-third of total coal shipments.

Emergency transportation measures that helped appreciably towards the increase of 30 million tons of coal movement in 1970 were the "permit" system established by the N. & W. and C. & O. Railroads, which limited shipments to tidewater only to those scheduled to coincide with ship arrivals at Hampton Roads; the doubling of demurrage rates by the Interstate Commerce Commission to discourage the accumulation of cars at transshipping facilities, consumer plants, and at non-operating mines; I.C.C. orders requiring the prompt return after unloading of open top cars to the owning railroads; and other actions which effected a better distribution of cars.

In the overall, however, the number of cars available for coal movement still is far below what is, and will be, required to assure adequacy of coal supplies, both in emergencies and as energy demand continues to accelerate. If developing and programmed increases in mining capacity are to be fully effective in supplying additional coal requirements, and if estimated future demands for coal are to be met, on both a short- and long-term basis (610 million tons of production in 1971, 690 million tons in 1975, and 933 million tons in 1980), it is vitally necessary that additional railroad cars and auxiliary transportation equipment, including locomotives, be made available from one source or another.

A 100-ton hopper car today costs approximately $16,000. To initiate a car-building program involving, for example, 2,000 of these cars, a railroad company is forced to spend about 32 million dollars.

It is understandable that necessary car-building expenditures are deferred by some large coal-carrying railroads as long as possible in view of their low level of earnings. These additional cars could be provided, however, by car building and leasing services, coal producers or consumers, government authorities, or otherwise, through private financing or governmental assistance or surveillance. Among possible alternatives for the latter are direct financing, guaranteed loans, tax incentives or penalties of one kind or another, subsidies, or other methods of funding. Whatever the means, something must be done, and the lead should be taken by those with primary responsibilities; i.e., the Interstate Commerce Commission and the Department of Transportation. Also, it may be necessary that the Government or others encourage research toward the development of less costly transportation methods and/or more reliable means of providing adequate coal or coal-produced energy at all times. The latter could include studies on the fundamental reasons for the decrease in car supplies and for the lack of replacement of retired equipment, the expanded use of coal slurry pipelines and of extra-high-voltage (EHV) transmission of coal-generated power from "minemouth" plants located in or near the coal fields, of railroad freight rate structures in relation to their compatibility with services rendered, and of whatever further authority is needed by the I.C.C. to establish such rules and regulations as may be necessary to assure better distribution of cars among essential commodities.

A shortage of hopper cars is a major problem in coal producing and marketing areas east of the Mississippi River because of the low earnings of certain Eastern carriers and their inability to maintain adequate rolling stock. One possible means of increasing car utilization by these carriers is to build on-ground storage facilities at the coal ports at Toledo, Hampton Roads and Newport News similar to those now in operation at Conneaut, Ashtabula, and Sandusky, Ohio. The proposition of ground storage facilities represents an attractive financial solution to hopper car shortages. It is estimated that construction of these facilities would release at least 25,000 hopper cars for use other than for the coal export and tidewater trade and would annually process 55 million tons of coal. It is estimated that these facilities would cost 50 million dollars versus 400 million dollars for the cars. Because of the current level of railroad earnings and shortage of capital it may be necessary that the Government consider a Federal investment of such a sum to initiate the program.

Overall, the existing coal transportation restrictions should ease somewhat as the trend of increasing production in Western States continues. In the West, transportation facilities are planned for adequately to coincide with increases in production whether it be in maintaining sufficient hopper-car fleets, the trend toward extra-high voltage transmission or coal pipelines such as the one now in operation from a mine in Arizona to a powerplant in Nevada.

In Eastern States the steady growth in river tonnage in recent years is expected to accelerate in the immediate years ahead and thereby, to some extent, ease the coal transportation burden of railroads. The major reasons for the anticipated growth in coal transportation on the inland waterway system include the following:

1. The long-range construction and expansion program of the Army Corps of Engineers to modernize and extend the inland waterway system.
2. The continuing improvement in the design of tow, barge and dock equipment to provide more efficient haulage and handling.
3. The continuing migration of industrial plants to river areas where ample supplies of water are available in addition to the availability of low-cost transportation of raw materials, and finished goods.

The importance of river transportation can be gauged by the fact that in 1969 more than 160 million tons of coal moved on the inland waterways. This waterway movement is concentrated largely in six areas:

1. Kanawha, Ohio and Monongahela Rivers to the Pittsburgh area.
2. Illinois River to the Chicago area.
3. Illinois and Mississippi Rivers to the Twin Cities area.
4. Western Kentucky to Tampa via the Ohio and Mississippi Rivers to New Orleans and across the Gulf.
5. Western Kentucky and southern Illinois to steam plants on the Lower Ohio, Mississippi and Tennessee Rivers.
6. Along the Black Warrior River in Alabama.

The Army Corps of Engineers is continually improving and extending the network of waterways. It is about to complete a new waterway known as the Arkansas-Verdigris Navigation System. This waterway when completed will make completely navigable for the first time a 436-mile section of the Arkansas River and its tributary, the Verdigris, from Catoosa, head of navigation for the system, to the Mississippi. It will link the Arkansas River with some 25,000 miles of inland and coastal waterways from the Great Lakes to the Gulf of Mexico, including such major industrial markets as Chicago, Cleveland and New Orleans.

This waterway will help in making it possible to open for development the vast coal resources adjacent to or within the so-called Arkansas Basin. About 160,000 square miles in area, the Basin covers most of Arkansas and Oklahoma, half of Kansas, the Texas Panhandle, and portions of Colorado, New Mexico and Missouri.

Figures 1, 2, and 3 show, respectively, bituminous coal and lignite production, serviceable railroad hopper cars, and the quantities of coal shipped from mines by various methods for the period 1966-1970.

In summary, the non-rail modes of transportation, in all likelihood, will be adequate in meeting the demands placed upon them. In order to assure adequate rail transportation, the following sequence of actions will assist in achieving the proper availability of hopper cars through 1975.

1. The intensified application of the Interstate Commerce Commission of its several powers in the area of car utilization, including the continuation of increased demurrage charges now in effect. Additionally, the Commission should further accelerate the formation of unit trains by encouraging appropriate rate adjustments and applications for service. Incentive per diem should be immediately levied on hoppers to encourage prompt return of cars and to foster equitable growth in ownership. Free time should be reduced from 48 to 24 hours, except at lake and tidewater ports, where gradual reduction should be made toward at least a 50 percent improvement.

Fig. 1 - Bituminous Coal and Lignite Production, 1966-70

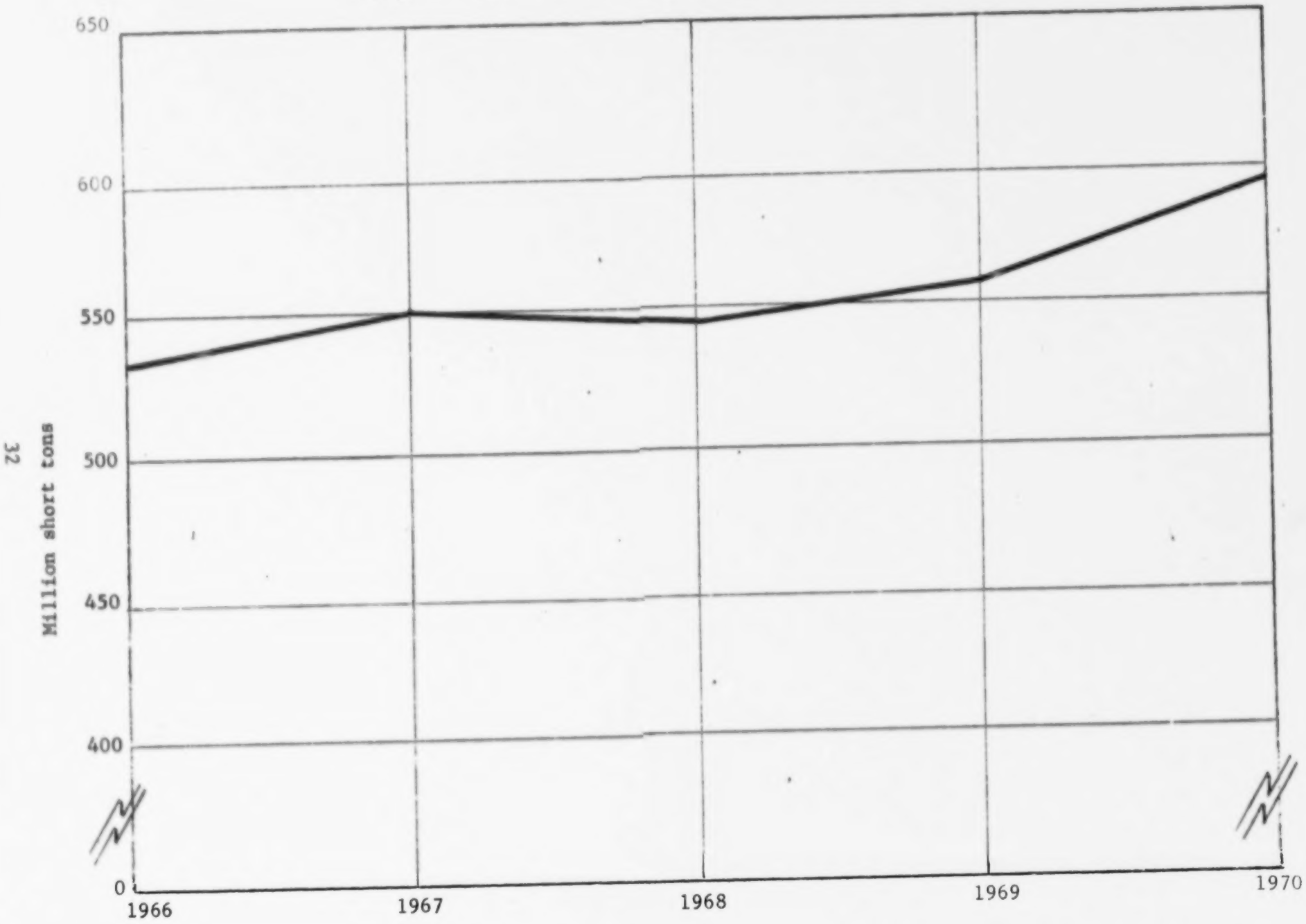


Fig. 2 - Railroad Serviceable Hopper Cars, 1966-70
(Excludes Privately Owned Cars on Class I Railroads)

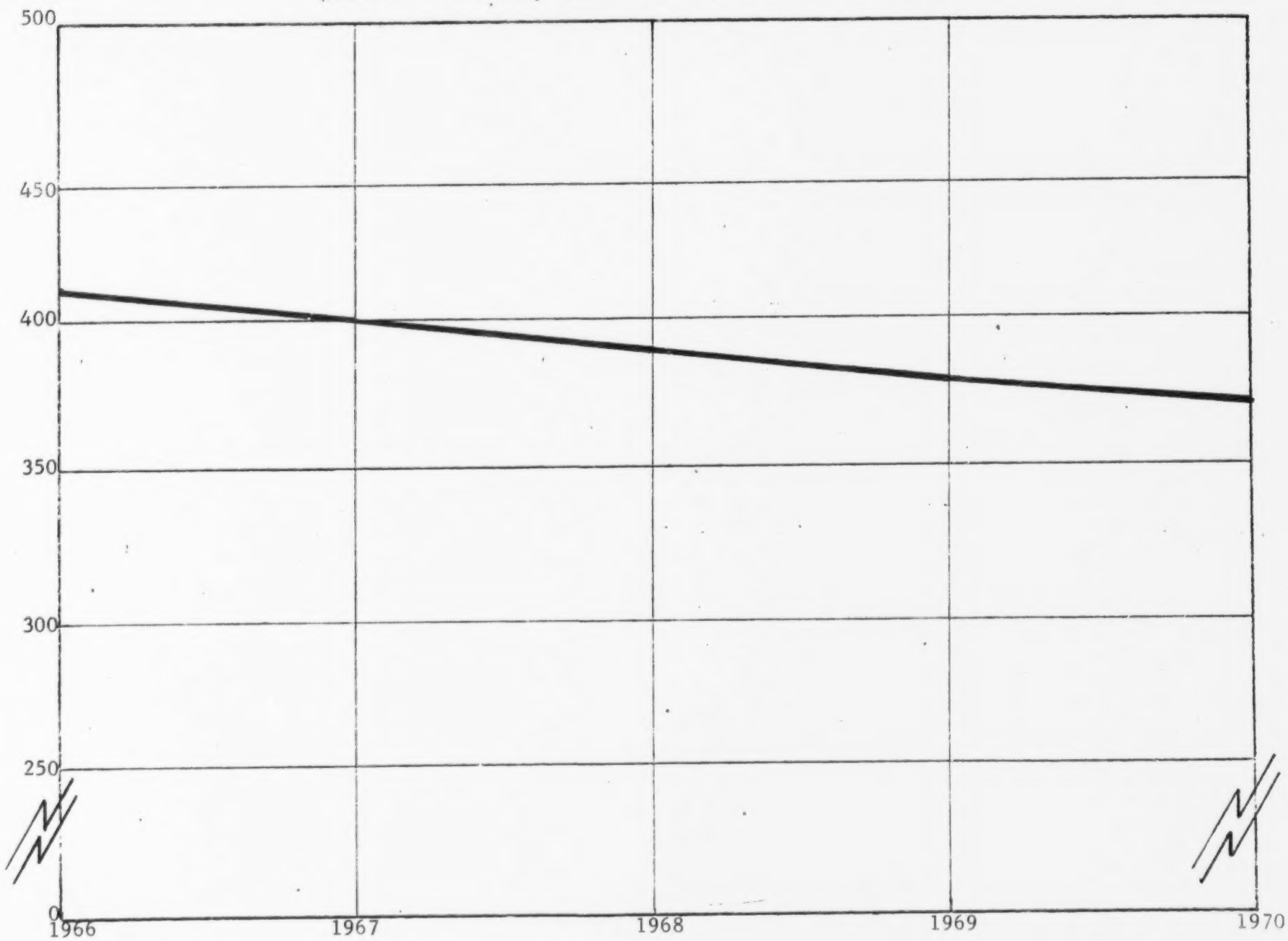
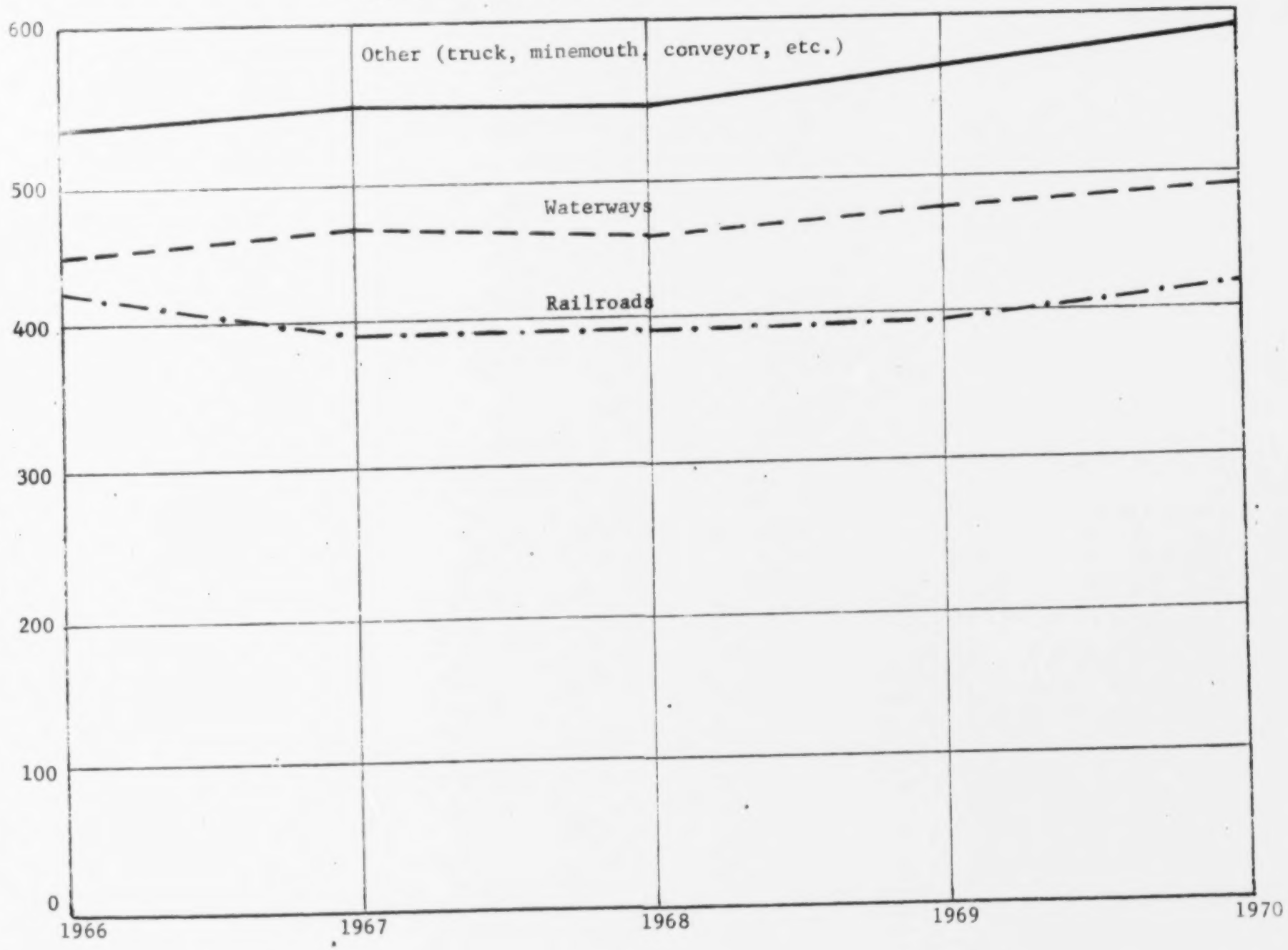


Fig. 3 - Transportation of Coal from Mines, 1966-70



2. For the immediate and long-term period, government assistance in financing new cars under a program administered by the I.C.C. should be made available to railroads with insufficient earnings to conduct their own car-building program.
3. Greater utilization of the existing fleet of hopper cars should be attained by construction of on-ground storage facilities at the coal ports at Toledo, Ohio and Hampton Roads and Newport News, Virginia.
4. It should be recommended that the Interstate Commerce Commission administer a program to guarantee loans to those coal-carrying railroads with inadequate hopper-car fleets.

Coal Preparation

Coal washing or cleaning refers to the removal of extraneous material such as pyrite, ash, or shale, from the raw coal. Other than froth flotation, coal cleaning processes are based primarily on the specific gravity of the materials present. High ash coal or coal middlings may also be separated. The greater the quantity of intermediate near gravity material, the more difficult is the cleaning process. An excellent reference on coal preparation has been published by the American Institute of Mining and Metallurgical Engineers. 1/

The Bureau of Mines published a report 2/ tabulating pyritic, sulfate, and total sulfur contents of 2,000 coal samples obtained in 29 states.

The term pyritic sulfur is used in reference to two crystal forms of iron sulfide, either pyrite or marcasite. The crystal structure is generally determined by the use of X-rays.

Macroscopic pyrite is present in the coalbed as veins, lenses, nodules or balls.

Microscopic pyrite occurs as small globules, discrete grains, cavity fillings, and crystalline bundles and aggregates. Published photomicrographs depict pyrite grains 1 to 2 microns in diameter.

1/ Leonard, Joseph W., and David R. Mitchel, and others, Coal Preparation, third edition, AIME, 1968.

2/ Walker, F. E. and F. E. Hartner, Forms of Sulfur in U.S. Coals, Bureau of Mines, I.C. 8301, 1966, 51 pp.

Theoretically, the pyrite and marcasite with specific gravities of 4.9 to 5.0 should be able to be removed from coal since coal is considered to have specific gravities of 1.2 to 1.7.

In coal washing practice the actual percentage of iron sulfides removed ranges greatly between coals from various coalbeds. If the pyrite is free (not in or attached to the coal particles) most of the pyrite can be rejected by the proper cleaning techniques. Sulfur in the forms of organic sulfur or sulfates is affected little by cleaning and in general cannot be removed.

Prior to the erection of a coal preparation plant, the coal property should be sampled at various points to assure a representative sample has been obtained of the area to be mined. A complete washability study should be made. Each set of coal washability curves 3/ presents the following curves. The cumulative ash and sulfur curves indicate the analysis in percent at a given yield of float coal. The specific-gravity curve indicates the yield of float coal at any given specific gravity. The + 0.10 specific-gravity curves indicate the distribution of near gravity of separation material and are used in estimating the difficulty of separation.

A size consist curve should be prepared to aid in the determining types and the required capacities of the cleaning equipment.

3/ Coe, G. D., and Explanation of Washability Curves for the Interpretation of Float-and-Sink, I.C. 7045, 1938, 10 pp.

An alternate procedure would be to run the raw coal through an existing coal preparation plant. Such a test would require a tonnage sufficient for several hours operation of the plant at or near its rated capacity. The results of one plant-test using 500 tons of raw coal were presented in Bureau of Mines R.I. 5397. 4/

In connection with the APCO program, face or tipple samples were taken at mines in the Appalachia Region. Each sample weighed about 600 pounds and was loaded into steel drums for shipment. At the laboratories, each coal sample was crushed to pass a 1 1/2-inch square mesh screen, and was reduced to about 250 pounds by quartering. The sample was dedusted by screening on a 100-mesh screen. Float-and-sink tests using organic liquids were made at the following gravities; 1.30, 1.40, 1.60.

Table 10 presents the results of laboratory separations of channel samples at 1.60 specific gravity. This specific gravity approximates the effective specific gravity at which many steam coals are cleaned. The float-sink fractions were analyzed for ash, pyrite sulfur, and total sulfur. Cumulating data from the float-sink fractions, the 100 percent yield shows the percentage of ash, pyritic sulfur, and total sulfur contents of the raw coal sample. The main purpose of presenting this table is to indicate coalbeds amenable to reduction in sulfur content by cleaning. In counties where more than one channel sample was taken, the results were averaged with some loss in accuracy. This was done to avoid too voluminous a table.

4/ Perry, R. E., B. W. Gandrud, H. L. Riley, J. B. Gayle, and W. H. Eddy, Laboratory and Full Scale Sulfur Elimination Tests on Coals from the Pratt Bed, Alabama, Bureau of Mines, R.I. 5397, 1958, 25 pp.

TABLE 10. - Float-and-sink data from coal channel samples 1/ showing reduction in ash and sulfur

Coalbed	State	County	Number of samples	PERCENT						
				Yield 2/	Ash in float 2/	Ash in sample	Ash reduction 2/	Sulfur in float 2/	Sulfur in sample	Sulfur reduction 2/
Pittsburgh	Ohio	Belmont	3	91.2	7.7	12.5	38.4	3.90	4.35	10.3
Do.	do.	Gallia	1	96.1	7.0	8.6	18.6	2.74	3.26	16.0
Do.	do.	Harrison	2	83.2	8.6	18.3	42.3	3.31	3.73	11.3
Do.	do.	Jefferson	5	90.9	8.6	13.5	36.3	3.26	3.66	10.9
Do.	Pa.	Greene	4	94.4	7.6	10.1	24.8	2.22	3.02	26.5
Do.	do.	Washington	1	93.7	5.6	8.5	34.1	1.50	1.67	10.2
Do.	W. Va.	Brooke	1	65.4	9.4	34.1	72.4	4.53	4.04	3/ 12.1
Do.	do.	Harrison	3	93.5	7.4	10.1	26.0	3.56	5.01	28.9
Do.	do.	Marion	3	94.5	6.5	9.4	30.9	2.24	2.98	24.8
Do.	do.	Marshall	2	91.2	7.5	10.9	31.2	3.42	4.40	22.3
Do.	do.	Monongalia	2	95.9	8.0	9.7	17.5	2.31	2.75	16.0
Do.	do.	Ohio	2	92.7	6.6	8.9	25.8	3.13	3.61	13.3
America	Alabama	Walker	1	83.7	7.1	13.9	48.9	1.52	1.71	11.1
Clements	do.	do.	1	90.5	8.8	13.5	34.8	3.40	3.75	9.3
Gwin	do.	Jefferson	1	91.6	14.1	16.3	12.9	1.47	1.77	16.9
Mary Lee	do.	do.	2	87.9	10.0	16.5	39.4	.88	.89	1.1
Bakerstown	Md.	Allegany	1	80.5	15.8	21.8	27.5	1.97	2.61	24.5
Do.	do.	do.	1	92.7	10.2	13.2	22.7	2.31	2.80	17.5
Jawbone	Va.	Russell	1	84.2	10.3	20.2	49.0	.58	.54	3/ 7.4
Upper Banner	Va.	Dickenson	1	87.7	5.3	12.8	58.6	.66	.69	4.3
Splash Dam	do.	do.	1	76.2	5.8	21.9	73.5	.83	.80	3/ 3.8
Tiller	do.	Russell	1	95.2	4.8	7.5	3.6	.48	.47	3/ 2.1
Upper Freeport	Pa.	Allegheny	1	78.7	10.0	22.5	77.6	1.52	1.90	20.0
Do.	do.	Armstrong	2	72.3	13.2	28.0	52.9	1.39	2.01	30.8
Do.	do.	Butler	1	81.0	10.6	20.4	48.0	1.20	1.28	6.3
Do.	do.	Cambria	1	81.4	8.6	18.6	53.8	2.30	4.47	48.5

See footnotes at end of table.

TABLE 10. - Float-and-sink data from coal channel samples 1/ showing reduction in ash and sulfur - Continued

Coalbed	State	County	Number of samples	PERCENT						
				Yield 2/	Ash in float 2/	Ash in sample	Ash reduction 2/	Sulfur in float 2/	Sulfur in sample	Sulfur reduction 2/
Upper Freeport	Pa.	Clearfield	3	81.7	10.6	17.9	40.8	3.29	4.83	31.9
Do.	do.	Tioga	1	96.3	8.3	10.0	17.0	.98	1.55	36.8
Do.	do.	Westmoreland	1	73.3	6.4	22.4	71.4	2.19	3.60	39.2
Do.	W. Va.	Grant	1	61.8	12.1	34.4	64.8	1.54	2.42	36.4
Do.	do.	Preston	1	89.2	9.0	13.7	34.3	1.19	1.53	22.2
Brookville	Ohio	Mahoning	1	95.3	5.4	5.7	5.3	2.06	2.60	20.8
Do.	do.	Jackson	1	90.5	4.9	10.3	52.4	3.20	4.03	20.6
Do.	Pa.	Lawrence	1	96.6	3.4	4.8	29.2	1.55	2.35	34.0
Clairon	do.	Clairon	2	90.2	8.0			2.33	3.39	31.3
Lower Bakerston	W. Va.	Grant	1	63.1	12.3	29.1	57.7	1.36	3.01	54.8
Mahoning	Ohio	Guernsey	1	70.3	8.6	28.3	69.6	3.73	4.44	18.4
Middle Kittaning	do.	Columbia	4	89.6	5.6	11.2	50.0	2.29	3.85	40.5
Do.	do.	Perry	3	82.5	10.0	18.5	45.9	2.39	4.71	49.3
Do.	do.	Muskingum	1	95.7	4.4	6.4	31.3	2.31	2.99	22.7
Do.	do.	Tuscarawas	2	85.3	5.6	13.2	57.6	2.94	5.40	45.6
Do.	Pa.	Clairon	1	98.1	6.6	6.7	1.5	.79	.80	1.3
Do.	W. Va.	Barbour	1	81.4	10.9	18.5	41.1	1.86	2.68	30.6
Lower Kittaning	Ohio	Jefferson	1	84.4	9.2	17.3	46.8	2.95	3.80	22.4
Do.	do.	Lawrence	1	88.1	9.4	14.4	34.7	3.35	4.72	29.0
Do.	do.	Muskingum	1	93.3	9.6	11.6	17.2	3.84	4.85	20.8
Do.	Pa.	Armstrong	1	84.1	8.4	16.5	49.1	3.42	5.09	32.8
Do.	do.	Bedford	1	84.9	6.6	13.5	51.1	1.03	2.06	50.0
Do.	do.	Cambria	2	79.8	8.7	19.0	54.2	.81	1.43	43.4

See footnotes at end of table.

TABLE 10. - Float-and-sink data from coal channel samples 1/ showing reduction in ash and sulfur - Continued

Coalbed	State	County	Number of samples	PERCENT						
				Yield 2/	Ash in float 2/	Ash in sample	Ash reduction 2/	Sulfur in float 2/	Sulfur in sample	Sulfur reduction 2/
Lower Kittaning	Pa.	Clairion	1	92.0	6.5	9.5	31.6	2.24	3.65	38.6
Do.	do.	Indiana	7	84.5	6.6	14.5	54.5	1.87	3.94	52.5
Do.	do.	Jefferson	1	96.9	7.1	8.4	15.5	1.12	1.34	16.4
Sewickley	Ohio	Belmont	1	95.6	12.0	13.3	9.8	2.57	3.03	15.2
Do.	do.	Harrison	2	96.6	9.9	11.0	10.0	1.66	2.08	20.2
Do.	do.	Morgan	2	87.5	12.4	17.0	27.1	4.77	5.54	13.9
Do.	do.	Noble	3	92.3	13.2	15.6	15.4	5.01	5.70	12.1
Do.	W. Va.	Monongalia	1	92.9	10.4	13.3	21.8	3.56	4.56	21.9
Jordon	Tenn.	Claiborne	1	98.1	3.0	4.0	25.0	.69	.76	9.2
Klondike	Tenn.	Anderson	1	94.7	7.1	9.1	22.0	1.06	1.99	46.7
Sewanee	do.	Marion	1	96.0	8.2	10.8	24.0	.67	.71	5.6
Walnut Mountain	do.	Campbell	1	92.4	5.3	10.0	47.0	.71	.81	18.1

1/ Minus 1 1/2 inch by 100 mesh.
2/ At 1.60 specific gravity.
3/ Increase.

Table 11 was compiled from a series of Bureau of Mines reports of investigations. The report number is listed in the table. When the raw coal sample contained less than one percent sulfur, sulfur analyses were not run on the float-and-sink fractions.

A short description is given of float-and-sink results on seven coalbeds which have some of the largest reported reserves.

Currently additional float-and-sink tests are being conducted by the Bureau for EPA. Additional coal preparation data will be needed to estimate the percentage of coal reserves which can be mined and upgraded to the desired standards.

Twenty-nine channel samples were taken from the Pittsburgh coalbeds in twelve counties in Ohio, Pennsylvania, and West Virginia. Five channel samples from Greene, and Washington Counties, Pennsylvania, and Marion and Monongalia Counties in West Virginia had float 1.60 fractions with 1.1 to 2.0 percent sulfur content.

The Pocahontas No. 3 coalbed has been sampled in conjunction with coking coal reports in Buchanan, Dickenson, and Tazewell Counties in Virginia, and in Mercer, Raleigh, and Wyoming Counties in West Virginia. The ash content in the cleaned coal should be 6.0 percent or less. The total sulfur content is less than 1.0 percent in the raw coal. This coal is used in coal blends to make metallurgical coke.

The Mary Lee Coalbed in Warrior Coalfield in Alabama was channel sampled. The float 1.60 fractions contained 0.7 and 1.1 percent total sulfur, respectively. The ash content of the float product averaged 10.0 percent. In Jefferson County the washed coal is used in blends for coke production.

TABLE 11.- Selected float-and-sink data on coals 1/ from published reports

Coalbed	State	County	Yield	PERCENT Ash in float	Ash in sample	Sulfur in float	Sulfur in sample	Reduction of sulfur	BuMines Rept of Inv. No.
Upper Elkhorn #3 or Cedar Grove	Kentucky	Floyd	94.0	3.4	6.9	1.06	1.49	28.9	4920
		Harlan	97.4	1.8	3.1		2/ 1.0		5140
		Knott	98.0	3.4	4.1	1.76	1.96	10.2	4993
		Knott	83.3	4.6	16.7		2/ 1.00		4993
		Letcher	99.4	3.5	3.8	1.16	1.21	.4	5135
		Letcher	76.8	2.9	21.6		2/ 1.00		5135
		Pike	85.6	5.5	13.4	2.25	3.64	38.2	4910
		Pike	95.6	5.5	7.5	.68	.87	21.2	4910
Cedar Grove	West Virginia	Boone	3/ 92.3	5.3	9.0		2/ 0.8		5909
		Boone	3/ 95.2	4.1	6.3	1.06	1.26	15.9	5909
		Kanawha	3/ 98.3	4.9	5.7	1.33	1.59	16.4	6296
		Kanawha	3/ 97.5	3.8	5.0	1.14	1.29	11.6	6296
		Logan	93.8	4.1	7.6	1.27	1.91	33.5	5306
		Logan	88.9	6.8	12.8	1.07	1.43	25.2	5306
		Logan	94.4	7.4	10.3	1.10	1.18	6.8	5306
		McDowell	85.7	5.6	15.2		2/ 1.0		5094
		Mingo	88.5	4.1	12.1		2/ 1.0		5278
Eagle	West Virginia	McDowell	95.1	4.6	6.8	1.11	1.21	8.3	509[illegible]
		Nicholas	3/ 91.3	5.8	9.5		2/ 0.7		6136
		Nicholas	3/ 95.3	5.7	7.4		2/ 0.7		6136
		Raleigh	86.6	5.1	14.0		1.0		5070
		Raleigh	79.2	4.9	20.4		2/ 0.6		5070
	Virginia	Buchanan	88.6	2.9	10.1		2/ 0.8		6740
Fire Clay	Kentucky	Perry	98.6	3.4	3.9	0.65	0.87	25.3	5230

See footnotes at end of table.

TABLE 11. - Selected float-and-sink data on coals 1/ from published reports - Continued

Coalbed	State	County	Yield	PERCENT Ash in float	Ash in sample	Sulfur in float	Sulfur in sample	Reduction of sulfur	BuMines Rept. of Inv. No.
Flagg	Kentucky	Perry	93.2	7.2	9.4		2/ 0.9		5230
Harlan	Kentucky	Harlan	99.2	2.3	2.7		2/ 1.0		5140
Hindman	Kentucky	Harlan	99.2	3.4	3.8		2/ 1.0		5140
Lower Elkhorn or Imboden	Kentucky	Letcher	84.5	7.4	15.7	1.07	1.36	21.3	5135
		Pike	82.7	3.6	16.4		2/ 1.0		4910
		Pike	95.6	5.7	8.1		2/ 1.0		4910
		Pike	95.3	6.8	9.1		2/ 1.0		4910
	Virginia	Wise	95.7	5.3	7.3		2/ 0.8		5391
Pocahontas #3	West Virginia	Mercer	94.5	4.7	6.9		2/ 0.9		6227
		Raleigh	96.2	6.0	7.5		0.8		5070
		Wyoming	86.6	5.9	13.0		2/ 0.7		5112
	Virginia	Buchanan	3/ 92.3	3.2	7.7	6.4	0.61	4/ .5	6740
		Dickenson	93.1	5.6	10.2		2/ 0.9		5405
		Tazewell	3/ 96.5	4.9	6.6		2/ 0.5		6297

1/ Minus 1 1/2-inch by 100 mesh.
2/ Raw coal.
3/ All specific gravities of separation 1.60 except that those indicated by footnote were 1.58.
4/ Increase in sulfur content.

Based on published data, a sample of the Lower Elkhorn coalbed in Letcher County, Kentucky, yielded a float 1.60 specific gravity fraction of 1.1 percent sulfur. In Pike County, Kentucky and Wise County, Virginia, four samples of raw coal from this bed had a sulfur content of less than 1.0 percent.

Sixteen channel samples were taken in the Lower Kittanning coalbed at 15 mines in 8 counties located in Ohio and Pennsylvania. In four samples, the float 1.60 fractions contained 1.0 or less total sulfur. For five, the float 1.60 fractions ranged from 1.1 to 2.0 percent total sulfur. The balance exceeded 2.1 percent. The coal samples obtained in Cambria and Bedford Counties, Pennsylvania indicate the coals from the Lower Kittanning coalbed should be capable of being cleaned to 1.0 percent sulfur or less.

Based on published literature, 16 references to float-and-sink tests were tabulated on the Upper Elkhorn No. 3 or Cedar Grove in Floyd, Knott, Letcher, and Pike Counties in Kentucky and Boone, Kanawha, Logan, McDowell and Mingo Counties in West Virginia. Six samples of raw coal had a sulfur content of less than 1.0 percent. Eight float 1.60 fractions had a sulfur content of 1.1 to 1.5 percent.

One sample from the Eagle coalbed in McDowell County, West Virginia had a float 1.60 fraction with 1.0 percent sulfur. Five other raw coal samples, from the Eagle coalbed in Nicholas and Raleigh Counties, and Buchanan County in Virginia had less than 1.0 percent sulfur.

Coal Preparation Plant Capacity and Availability

In 1969, the total production of bituminous coal and lignite was 560.5 million tons. Of this production 334.8 million tons, or 59.7 percent was cleaned by wet and pneumatic methods. According to one trade journal, the cleaned coal capacity of coal cleaning equipment sold in 1970 totaled 20.1 thousand tons per hour compared with 11.6 thousand tons per hour for equipment sold in 1969. Based on an estimated use of 12 hours per day and 220 days per year, 53.1 million tons of cleaned coal capacity was added in 1970. This added capacity was about 9 percent of the estimated 1970 coal production.

The lead time, from signing the contract to the time the preparation plant is operational, may range from one to two years. This lead time does not include the time required for coal sampling or coal washability tests.

Several companies building new facilities reported three to four bidders on contracts to erect coal washability plants. Considering that 59.7 percent of the 1969 production was cleaned, and plant capacity in 1970 increased 9 percent, the erectors should be able to keep up with a normal increase in demand for new preparation plants.

New bituminous coal preparation facilities contracted for in 1970 are shown in Table 12.

TABLE 12. - New Bituminous Coal Preparation Facilities Contracted for in 1970

Coal company	Plant location	Capacity, tph	Preparation equipment
Alabama Power Co.	Gorgas, Ala.	1,600	McNally Pittsburg
Allegheny Mining Corp.	Mt. Storm W. Va.	200	Irvin-McKelvy
Allegheny River Mining Co.	Kittanning, Pa.	600	Irvin-McKelvy
Amherst Coal Co.	Logan, W. Va.	300	Bird Machine
	Slagle, W. Va.	400	Dravo[1,6]; Heyl & Patterson
Arch Minerals	Fabius, Ala.	500	McNally Pittsburg
	Belle Rive, Ill.	800	McNally Pittsburg
Armco Steel Corp.	Montcoal, W. Va.	...	Kanawha
	Twilight, W. VA.	...	
Badger Coal Co.	Philippi, W. Va.	...	Daniels
Barnes & Tucker Co.	Barnesboro, Pa.	...	Heyl & Patterson
	Carrolltown, Pa.	250	J.O. Lively
Beaver Creek Consolidated Coal Co.	Wayland, Ky.	650	Heyl & Patterson; McNally Pittsburg; Deister
Bethlehem Mines Corp.	Jenkins, Ky.	...	Heyl & Patterson
	Kayford, W. Va.	650	McNally Pittsburg; Heyl&Patterson
Boone County Coal Corp.	Moncio, W. Va.	...	Heyl & Patterson
	Sharples, W. Va.	250	Daniels; Deister
Buffalo Mining Co.	Kermit, W. Va.	...	Daniels
Cannelton Coal Co.	Cannelton, W. VA.	...	Daniels
Carbon Fuel Co.	Carbon, W. Va.	...	Galis
	Wevaco, W. Va.	324	McNally Pittsburg; Galis
	Winefrede, W. Va.	...	Heyl & Patterson; Galis
C&K Coal Co.	Clarion, Pa.	400	Irvin-McKelvy
Central Coal Co.	New Haven, W. Va.	...	McNally Pittsburg; Bird Machine
CF&I Steel Corp.	Pueblo, Colo.	...	Roberts & Schaefer
Clinchfield Coal Co.	Feds Creek, Ky.	200	Dravo; Bird
	Mouthcard, Ky.	...	Dravo
	Clinchfield, Va.	20	Bird
Consolidation Coal Co.	Beckley, W. Va.	...	Heyl & Patterson
	Raleigh, W. Va.	20	Bird
Eastern Associated Coal Corp.	Affinity, W. Va.	400	Roberts & Schaefer
	Boone County, W. VA.	...	Roberts & Schaefer
Eastern Coal Corp.	Stone, Ky.	25	Dravo; Bird Machine
Enos Coal Corp.	Enosville, Ind.	...	Heyl & Patterson
	Oakland City, Ind.	...	Roberts & Schaefer
Feds Creek Coal Co.	Dunlap, Ky.	200	Zeni-McKinney-Williams; Deister
	Pike County, Ky.	...	Dravo

TABLE 12. - New Bituminous Coal Preparation Facilities Contracted for in 1970

(continued)

Coal company	Plant location	Capacity, tph	Preparation equipment
Fording Coal Ltd.	British Columbia, Cana.	700	Bird Machine
Helen Mining Co.	Seward, Pa.	75	Irvin-McKelvy
Hill Gail Coal Co. Inc.	Whitesburg, Ky.	350	Powered Equipment Inc.
Island Creek Coal Co.	East Morganfield, Ky.	...	J.O. Lively
	Madisonville, Ky.	1,000	Powered Equipment Inc.
	Tire Hill, Pa.	...	Irvin-McKelvy
	Buchanan County, Va.	625	McNally Pittsburg
	Vansant, Va.	...	McNally Pittsburg
	Matoaka, W. Va.	...	Daniels / Deister
	Werth, W. Va.	90	Bird Machine
Jewell Ridge Coal Corp.	Jewell Valley, Va.	500	McNally Pittsburg / Daniels
Kanawha Coal Co.	Ashford, W. Va.	400	Roberts & Schaefer
Kentland-Elkhorn Coal Co.	Dunlap, Ky.	...	Heyl & Patterson
Martin County Coal Corp.	Ines, Ky.	1,000	Daniels / Deister / Heyl & Patterson
Moffat Coal Co.	Murdoch, Ill.	70	Bird Machine
North American Coal Co.	Powhatan Pt., O. (Q)	600	J.O. Lively
	Powhatan Pt., O. (N)	1,200	
Old Ben Coal Corp.	Sesser, Ill	...	Roberts & Schaefer
Omar Mining Co.	Madison, W. Va.	...	Heyl & Patterson
P.B.S. Coals, Inc.	Mercersburg, Pa.	200	Irvin-McKelvy
P&N Coal Co.	Punxsutawney, Pa.	250	Irvin-McKelvy
Peabody Coal Co.	Freeburg, Ill.	...	Heyl & Patterson
	Camp Breckenridge, Ky.	3,000	Powered Equipment Inc. / Heyl & Patterson
	Madisonville, Ky.	600	McNally Pittsburg
Pittsburgh Coal Co.	Renton, Pa.	...	Heyl & Patterson
Pocahontas Fuel Co.	Matoaka, W. Va.	50	Daniels / Deister
	McComas, W. Va.	75	Daniels / Deister
Pounding Mill Coal Co.	McCarr, Ky.	150	Jeffrey
Ranger Fuel Corp.	Bolt, W. Va.	250	J.O. Lively
Royalty Smokeless	Premier, W. Va.	200	McNally Pittsburg / Daniels
Rushton Mining Co.	Phillipsburg, Pa.	350	J.O. Lively
South East Coal Sales Co. Inc.	Whitesburg, Ky.	350	Powered Equipment Inc.
Tennessee Consolidated Coal	Jasper, Tenn.	400	Roberts & Schaefer
United Electric Coal Cos.	DuQuoin, Ill.	250	Bird Machine
United Pocahontas Coal Co.	Crumpler, W. Va.	25	Bird Machine
U.S. Steel Corp.	Lynch, Ky.	...	Galis / Heyl & Patterson
	Wyoming County, W.Va.	600	Allen & Garcia / Deister
	Pineville, W. Va.	594	Allen & Garcia / McNally Pittsburg
Winding Gulf Coals Inc.	Eccles, W. Va.	..	J.O. Lively

Effects of Health and Safety Regulations

Recently enacted Federal health and safety regulations will restrict coal availability principally from the standpoint of available manpower. However, a small amount of production is expected to be curtailed because of the closing of some marginal mines that can not afford to provide the required health and safety requisits.

Essentially, the regulations require continuous checks on ventilation and the accumulation of coal dust to insure against explosions; the inspection of roof support systems, electrical and mechanical equipment; and the virtual discontinuance of operations until all deficiencies in equipment and operating areas have been corrected. Undoubtedly, these requirements will have a profound effect upon productivity and, in effect, will increase manpower requirements. The implementation of these regulations are, primarily, the basis for our conservative estimate of 1 percent as the average annual rate of growth in productivity through 1985.

Major inovations in the Federal Coal Mine Health and Safety Act enacted in 1969 are the health standards which were enacted for the first time. These standards include limitations on respirable coal dust; control of rock dust from drilling holes for roof bolts; medical examinations, including chest roentgenogram; noise standards; furnishing potable water at the working place; and sanitary facilities.

The law also has standards for ventilation, mining and roof support plans, rock dusting, mine maps, blasting, lighting and communications. Standards for permissible electrical mining equipment, high

and low voltage electric power transmission, and for electrical grounding, and for trailing cables are included in the law. The Act also has requirements for fire protection, including water lines installed parallel to the entire length of belt conveyors and rail haulage ways.

The law further requires that, effective June 30, 1970, each operator shall continuously maintain the average concentration of respirable dust in the mine atmosphere during each shift and that the level of suspended dust to which each miner is exposed should be 3.0 milligrams or less per cubic meter of air.

Effective December 30, 1972, the concentration of respirative dust in the mine atmosphere shall be reduced to no more than 2.0 milligrams per cubic meter. The Act defines respirable dust as particulates 5 microns or smaller in size.

The mine operator must take the samples in a prescribed manner and mail these samples to the Bureau of Mines. The results of sampling were reported in Bureau of Mines Technical Progress Report 32, April 1971, as follows: "As of March 1, 1971, over 152,000 respirable dust samples have been processed by the Bureau of Mines. Approximately 75 percent of underground working sections are being sampled in accordance with Federal regulations. Results indicate that 72 percent of the sections which have completed at least one basic sampling cycle are below 3.0 mg/m^3, the (present) standard in effect under the Federal Coal Mine Health and Safety Act of 1969 (P. L. 91-173).

Notices of Violation were issued on 1,670 underground mines for failure to begin a sampling program; withdrawal orders were issued in 64 of these instances. Notices of Violation were issued on 1,121 sections were applicable dust levels were exceeded; withdrawal orders were issued in seven of these instances. There are 381 mining sections currently operating on permits from the Interim Compliance Panel."

The report's conclusions are:

"Assessment of data obtained from the operators' sampling program and Federal inspections indicates that the first level of Federal respirable dust standards is clearly attainable at this time. Many coal mines are now registering remarkably low respirable dust concentrations. Although previous work done by the Bureau of Mines indicated that miners working in "high-risk" areas had an average exposure of 5.6 mg/m^3, an assessment after 8 months under the act indicates that the exposure of a significant percentage of such miners is now between 2 and 3 mg/m^3. Furthermore, 45 percent of the working sections which have completed a basic sampling cycle have dust concentrations lower than 2.0 mg/m^3. This indicated real promise for the achievement of the 2.0 mg/m^3 standard when it takes effect on December 30, 1972."

In general, the reduction in respiratory dust has been achieved by more and better water sprays available at the coal face, increased ventilation at the face, and better brattice maintenance.

The Act also requires that dust from drilling in rock shall be controlled by the use of permissible dust collectors, or by water, or water and wetting agents.

In general, after one year from the effective date of this Act, all low horsepower electrical equipment taken in by the last open cross cut must be permissible. This includes items such as hand-held electric drills, blower and exhaust fans, electric pumps, etc. In addition, all junction or distribution boxes used for making multiple power connections must be permissible.

For coal mines, which have coalbeds above the water table and which have not been declared gassy, a permit for non-compliance may be granted to allow the use of non-permissible equipment. However, permits for non-compliance will not be given to exceed 48 months after the enactment of this act. After one year from enactment, all replacement equipment acquired for use in any mine must be permissible and so maintained.

Any coal mine classed as gassy prior to the operative date of this Act shall continue to use permissible equipment.

Each operator shall carry out a continuing program to improve the roof control system. The roof and ribs of all active underground roadways, travel ways, and working places shall be supported or adequately controlled to protect personnel from falls of the roof or ribs.

The Act states "A roof control plan and revisions thereof suitable to roof conditions and mining system of each coal mine and approved by the Secretary shall be adopted and set out in printed form within sixty days after the operative date of this act. The plan shall show the type of support and spacing approved by the Secretary. Such plan shall be reviewed periodically, at least

every six months by the Secretary, taking into consideration any falls of roof or ribs or inadequacy of support of roof or ribs. No person shall proceed beyond the last permanent support unless adequate temporary support is provided or unless such temporary support is not required under the approved roof control plan and the absence of such support will not pose a hazard to the miners. A copy of the plan shall be furnished the Secretary or his authorized representative and shall be available to the miners and their representatives."--"When installation of roof bolts is permitted, such roof bolts shall be tested in accordance with the approved roof control plan."

In summary, specific measurement of production losses is difficult at the present. In Bureau of Mines personnel's conversations with mine operating officials, expressions of opinion are that decreases of productivity may range from 10 to 25 percent. However, losses in productivity at individual mines or the closure of marginal mines appears to have been compensated for by the opening of new mines, additional sections in older mines, and increased employment.

The production of bituminous coal increased from 560.5 million tons in 1969 to an estimated 596.5 million tons in 1970, or an increase of 6.4 percent.

In an attempt to evaluate the effect of current safety requirements on production per man-hour and per man-day, the estimated production and estimated man-hours for the combined months of August through December in 1969 were compared with the same months in 1970.

The man-hours estimates were compiled from monthly reports submitted to the Bureau of Mines from operators producing approximately 80 percent of the Nation's bituminous coal and lignite. Production data are estimates based on railroad carloadings and river shipments with an allowance made for truck shipments and coal used at mines. We wish to point out that normally these statistics would not be used to determine productivity. However, at this time, these are the only available data with which we can tend to evaluate this impact. The tonnages and man-hours include surface and underground production. The tons per man-hour are as follows:

	1969	1970	Difference Tons/man-hour
August	2.4569	2.4381	- .0188
September	2.4234	2.4839	+ .0605
October	2.4718	2.3971	- .0747
November	2.4669	2.4708	+ .0039
December	2.5288	2.3286	- .2002
Average	2.4694	2.4220	- .0474

The tons per man-hour August to December 1969 period was 2.4694 in 1969 and 2.4220 for the 1970 period. Based on an 8-hour work day, the tons per man-day were 19.76 for the 1969 period and 19.38 for 1970, or a decline of 0.38 tons.

In 1969, 61.9 percent of the coal was produced in underground mines. Assuming the same ratio existed in 1970, the reduction in tons per man-day would be:

$$.38 \div .619 = .613 \text{ tons per man-day}$$

Based on the average, the decline is a little more than 0.6 tons per man-day.

The Health and Safety Act will increase mining costs and the coal's market value.

If a company delays ordering permissible equipment too long, or does not have its equipment made permissible and maintained in this condition, a drop in this company's production will result from lack of usable equipment. If this condition becomes widespread, total coal production could decline.

Current lead times for equipment purchases such as a small continuous miner are reported to be 9 to 18 months. Current lead times for conventional equipment was estimated at 12 to 18 months. One medium size mine has its name on the manufacturer's list for conventional equipment as far in advance as 1975. This company plans to replace present equipment within four to five years.

Summary

In summation, the following points are emphasized:

1. Coals vary greatly in chemical and physical properties and one rank of coal can not be generally substituted for another. Even coals of the same rank can not be interchanged, in many instances, for one another.
2. A problem of immediate concern to electric-utility plants in some areas is the procurement of low-sulfur coals with ash-fusion temperatures suitable for use in wet-bottom furnaces. It appears that demand for such coals in the near future will far outweigh supply.
3. Manpower needs of the coal industry are expected to increase substantially during the next decade and the industry is faced particularly with the problem of attracting and recruiting the needed manpower at a time when its image has grossly deteriorated because of recent mining disasters, health problems of miners, and undesirable working conditions. A number of interrelated factors will, of course, affect requirements, but it is estimated that the additional miners that will be needed to produce the coal that will be required in 1985 will range from a low of 26,000 to a high of 184,000.
4. Non-rail modes of coal transportation will, in all probability, be adequate to meet the demands placed upon them. Railroad transportation will, however, not be adequate unless the actions mentioned in the report, or others, are instituted to increase the supply of railroad hopper cars.

5. Coal preparation and cleaning plant capacity must be expanded greatly in order that the coal industry can meet the more severe requirements being imposed upon coal quality. Presently, from 1 to 2 years elapses between the times when initial construction of a coal preparation plant begins and the plant is completed and becomes operational. It should be recognized that there is a relatively small number of companies that construct coal preparation plants and that any large influx of orders for such plants will greatly extend the time span for delivery.

6. The Federal Coal Mine Health and Safety Act of 1969 is expected to restrict coal availability, principally because it is expected to lower productivity and increase manpower requirements. As assessment of the effects of health and safety legislation upon coal availability is premature at this time because of the lack of data.